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Trends in the abundance and size-composition of snow crab (*Chionoecetes opilio*) in the September multi-species bottom trawl survey of the southern Gulf of St. Lawrence, 1980-2011

Tendances liées à l'abondance et à la composition selon la taille, des stocks de crabes des neiges (*Chionoecetes opilio)* lors des relevés plurispécifiques au chalut de fond effectués en septembre dans le sud du golfe du Saint-Laurent, 1980-2011

H.P. Benoît

Fisheries and Oceans Canada / Pêches et Océans Canada
Science Branch / Secteur des Sciences
P.O. Box 5030 / C.-P. 5030
Moncton (NB)
E1C 9B6

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ABSTRACT

The assessment for the southern Gulf of St. Lawrence snow crab (*Chionoecetes opilio*) stock has been founded in large part on a dedicated fishery-independent bottom-trawl survey undertaken annually since 1988. Another standardized research vessel (RV) bottom-trawl survey of the southern Gulf (henceforth the RV survey) has been undertaken annually in September since 1971 and has principally been used for assessments and scientific research dedicated to marine fish. As part of a November 2011 framework assessment for southern Gulf snow crab, the RV survey was shown to provide reliable indices of abundance, distribution and habitat use of commercial male snow crab for 2001-present and of all snow crab (aggregated index) for 1980-present. In this research document, such indices from the RV survey are presented in support of the indices produced by the crab survey for the 2012 regional assessment process for the stock, which took place in Moncton, NB on February 7-8. Of particular note, the RV survey confirms an important increase in the abundance of commercial-sized adult male snow crab observed in the crab survey following the 2011 commercial fishery.

RÉSUMÉ

L'évaluation du stock de crabes des neiges (*Chionoecetes opilio*) du sud du golfe du Saint-Laurent dépend en grande partie des données obtenues par un relevé au chalut de fond indépendant de la pêche, effectué annuellement depuis 1988. Un autre relevé normalisé au chalut de fond, effectué par un navire de recherche (NR) dans le sud du golfe (ci-après nommé relevé du NR), a été entrepris sur une base annuelle, au mois de septembre, depuis 1971 et a principalement été utilisé pour les évaluations et la recherche scientifique concernant les poissons marins. Dans le cadre d'une évaluation du cadre pour le crabe des neiges du sud du golfe réalisée en novembre 2011, il s'est avéré que le relevé du NR fourni des indices fiables d'abondance, de répartition et d'utilisation de l'habitat pour le crabe des neiges commercial mâle depuis 2001, et pour tous les crabes (indice agrégé) depuis 1980. Dans le présent document de recherche, les indices du relevé du NR sont présentés en appui aux indices produits par le relevé spécifique pour le stock de crabes dans le cadre du processus d'évaluation régionale de 2012, lequel a été effectué à Moncton, au N.-B., les 7 et 8 février. Il convient de noter que le relevé du NR confirme une importante augmentation de l'abondance de crabes des neiges mâles adultes de taille commerciale dans le relevé sur les crabes suivant la pêche commerciale de 2011.

INTRODUCTION

The assessment for the southern Gulf of St. Lawrence snow crab (*Chionoecetes opilio*) stock has been founded in large part on a dedicated bottom-trawl survey, undertaken annually since 1988 (except in 1996), to provide a fishery-independent index of stock status (Hébert et al. 2011). Another standardized research vessel (RV) bottom-trawl survey of the southern Gulf (henceforth the RV survey) has been undertaken each September since 1971 and has principally been used for assessments and scientific research dedicated to marine fish (e.g., Hurlbut et al. 2010; Benoît and Swain 2008). Catches of snow crab in this survey have been recorded since 1980 and since 2001 the carapace size composition of those catches has also been recorded. A recent evaluation undertaken as part of the November 2011 framework assessment for southern Gulf snow crab demonstrated that the RV survey produces a summary of southern Gulf snow crab relative abundance, distribution and size composition that is comparable to that obtained from the dedicated snow crab survey (Benoît 2012). The RV survey provides synoptic estimates of snow crab abundance and distribution for an area of the southern Gulf of St. Lawrence that is larger than that covered by the crab survey and that is consistently sampled over time. The information from the standardized RV survey therefore has a strong potential for helping to address key problems with the snow crab survey related geographic areas that were unsampled in the past, as well as in addressing possible changes in catchability that resulted from uncalibrated vessel changes that have occurred in the crab survey (Benoît 2012). Furthermore, the RV survey has the potential to enhance understanding of southern Gulf snow crab stock productivity and dynamics by extending abundance indices back to 1980.

In this research document, indices of snow crab abundance, distribution and size composition from the RV survey are presented in support of the indices produced by the crab survey for the 2012 regional assessment process for the stock, which took place in Moncton, NB on February 7-8. Of particular note, the RV survey confirms an important increase in the abundance of commercial-sized adult male snow crab observed in the crab survey following the 2011 commercial fishery.

METHODS

The September multi-species RV survey

The RV survey has been undertaken each September since 1971. It follows a random-stratified design, with strata defined on the basis of depth and area (Fig. 1) (see Hurlbut and Clay 1990 for details on the survey methodology). A common group of strata has been sampled annually since 1971, covering most of the southern Gulf of St. Lawrence (Northwest Atlantic Fishery Organization area 4T). Three inshore strata (strata 401, 402 and 403) were added in 1984, but are not included in the present analyses because they fall outside the distribution of snow crab and because I wanted to maintain the consistency of the time series presented. The target fishing procedure at each station during the survey is a 30-min. tow at 3.5 knots. The number of valid fishing sets completed annually has varied from approximately 70 during the early 1980s to 175 or more during the 1990s and 2000s. In 2011, 136 valid sets were completed.

Catches of snow crab (numbers and mass per tow) have consistently been recorded in the survey since 1980 (Tremblay 1997). Since 2001, captured crabs have also been measured and sexed, though maturity is not determined. Here, catches are standardized for the distance

towed in the set and are expressed either as a mean per standard tow of 1.75 nm or as trawlable abundance.

Fishing during the RV survey was carried out by the *E.E. Prince* from 1971 to 1985 using a Yankee-36 trawl. Since then, a number of different vessels have been used, each fishing a Western IIA trawl: the *Lady Hammond* (1985-1991), the CCGS *Alfred Needler* (1992-2002 and 2004-2005), the CCGS *Wilfred Templeman* (2003), and the CCGS *Teleost* (2004-present). Parameters for the trawls and vessels used in the RV survey are provided in Tables 1 and 2 respectively. Note that both trawls used in the survey are meant for fishing groundfish, though a liner is used in the codend to retain small animals. Though snow crab are routinely captured in the RV survey, the configuration of the footrope is such that catchability is much lower than in the crab survey (Benoît 2012).

The gear change and all of the vessel changes in the RV survey, except for the use of the CCGS *Wilfred Templeman* in 2003, involved comparative fishing to estimate the relative catchability of the vessels/gears when capturing various species of fish or macroinvertebrates (see Benoît and Swain 2003a; Benoît 2006). During the years in which the comparative fishing experiments between the CCGS *Alfred Needler* and the CCGS *Teleost* took place (2004 and 2005), both vessels were used to complete the surveys. Based on all of the comparative fishing experiments, the *E.E. Prince* fishing the Yankee-36 was found to be less efficient at capturing snow crab compared to the *Lady Hammond* and *CCGS Alfred Needler*, and corrections are applied to the data as a result (Benoît and Swain 2003a; Benoît 2006). Comparative fishing results also suggest that the *CCGS Teleost* may be more efficient at catching snow crab relative to the *CCGS Alfred Needler* and the *Lady Hammond*, though the statistical significance of the effect was very weak. As a result, the analyses presented here were undertaken separately either assuming that there was or there was not a difference in fishing efficiency between those vessels. Because the survey area was not completely covered in 2003 and the relative fishing efficiency of the vessel used that year (*CCGS W. Templeman*) is not known, data from 2003 have been omitted from the present analyses.

Fishing in the RV survey was restricted to daylight hours (07:00-19:00) from 1971 to 1984 but has been conducted 24 hours per day since 1985. Because fishing efficiency can vary by time of day as a result of species-specific diel behaviours such as hiding and trawl avoidance, survey catches are standardized post-hoc based on the results of analyses of survey catches and comparative fishing over the diel cycle (Benoît and Swain 2003b). Overall, from a size aggregated basis, snow crab are more catchable at night in the survey. However the diel effect is size dependent, with small crabs (<100 mm carapace width) being more catchable during the day, and larger crabs (≥100 mm) more catchable at night. For those years in which only snow crab numbers and biomass were recorded in the survey, a size-aggregated correction is applied. For subsequent years, the correction is size-specific (Benoît and Swain 2003a).

ANALYSIS

Trawlable abundance of adult male snow crab ≥95 mm in year t, RV_t, was calculated as:

$$RV_t = U \cdot p_t \cdot \sum_i \left(w_{i,t} \cdot \sum_{j=95}^{J\max} y_{i,j,t} \right) \quad 1)$$

for t=2001,...,2010 (excluding 2003), where U is the number of trawlable units in the inference area (i.e., surface area / area swept by a standard tow), p_t is the proportion of male crabs ≥95 mm that were mature in the summer of year t (taken from the snow crab assessment), w_i is the proportion of the RV survey area in the stratum fished by tow i in year t, divided by the number of tows made in that stratum, and $y_{i,j,t}$ is the standardized number of male crab of carapace width j caught in tow i in year t. Confidence intervals were calculated using the standard estimator for standard error based on stratified random sampling (Krebs 1989). Note that RV survey trawlable abundance greatly underestimates the actual abundance of snow crab because of low efficiency of the gear at catching crab. The relative efficiency of the RV survey compared to the crab survey is around 1-2% (Benoît 2012). Nonetheless because substantial efforts are undertaken to maintain the standardization of the RV survey (Benoît and Swain 2003a,b; Benoît 2006; Benoît et al. 2009), average efficiency should not have changed over time and the RV survey is very likely to produce relative abundance indices that reliably track actual abundance.

The length-aggregated biomass index for snow crab (mean kg/tow), B_t, was calculated as:

$$B_t = \sum_i w_{i,t} \cdot b_{i,t} \quad 2)$$

for t=1980,...,2010 (excluding 2003), where $b_{i,t}$ is the biomass (kg) of snow crab in set i of year t.

Analyses for RV_t and B_t were undertaken separately for catches by the *CCGS Teleost* that were and that weren't corrected for a possible difference in fishing efficiency relative to the *CCGS A. Needler*. Furthermore the analyses were undertaken for two geographic areas of inference: the snow crab assessment area used in recent assessments, representing 44,302 km^2, and the RV survey area exclusive of strata 401-403 (Fig. 1), representing 70,061 km^2

Catch rates of commercial-sized adult male snow crab in the RV survey (numbers/tow) were mapped using inverse distance weighted gradient interpolation. The contour levels for plotting were defined as the 10th, 25th, 50th, 75th and 90th percentiles of non-zero catches over the period of interest, 2001-2011 (excluding 2003).

RESULTS AND DISCUSSION

For the period 2001-2011, the abundance of large adult male snow crab increased from a relatively low level in 2001, to a relatively high level mid-decade, declining to the lowest levels of the 2000s in 2010 (Fig. 2). In 2011, the abundance of large adult male snow crab increased sharply to a level almost twice that observed in 2010. The trend is consistent whether abundance is calculated for the snow crab assessment inference area or the RV survey area,

though estimates for the latter are approximately 20-40% higher. When a correction is applied for the possible lower efficiency of the *CCGS Teleost* relative to the *CCGS Alfred Needler*, the trend also remains, though the peak abundance of the mid 2000s is relatively higher, as are the estimated abundances in the years that followed.

The RV survey size-aggregated biomass index provides a longer-term perspective of snow crab population dynamics in the southern Gulf (Fig. 3). Trends in this index during the 2000s generally match those observed for large adult male crab (Fig. 2). This is because the large males typically comprise the bulk of the biomass in the catches. To the extent that this was also true prior to 2001, the size-aggregated index would provide a reasonable proxy for the abundance of commercial-sized male crabs back to 1980.

The RV survey size-aggregated biomass index suggests that crab biomass since the mid-1990s has been low relative to levels observed in the early 1980s and in 1991, and in particular relative to the high level observed in 1990. The stock was at least 40-50% larger in certain years during the period prior to 1997, compared to the years in the period following, which are currently considered high abundance years for commercial sized male crabs. The magnitude of the changes since 1980 is such that a correction for a possible difference in catchability between the *CCGS Needler* and *Teleost* changes little the perceived dynamics of the stock over the entire series. Trends in the biomass index for the snow crab assessment area of 44302 km^2 are nearly identical to those for in the 70061 km^2 RV survey area that excludes strata 401-403.

The snow crab stock has undergone an important shift in distribution over the past 30 years. Prior to 1990, approximately 30-40% of the stock occurred in the Baie de Chaleurs and just outside its mouth (Fig. 4). Beginning in the early 1990s, this percentage dropped to between 10-20%, with a possible slight increasing trend since the mid 2000s. This observation has important consequences for efforts to reconstruct snow crab abundance during the late 1980s and early 1990s using exclusively data from the dedicated snow crab survey. Sampling in the crab survey during those years took place in a geographically limited area of the Baie and of the southern Gulf in general, thereby requiring considerable extrapolation of survey results to estimate total abundance (Hébert et al. 2011; Benoît 2012). The shift in distribution is such that there is little information in the crab survey to properly account for the higher abundances in the unsampled areas of the Baie. A careful analysis based in part or in whole on the RV survey data could help fill this void.

The size-frequency distributions of crabs in the RV survey are shown in Fig. 5. Generally speaking, the late 2000s were characterized by a higher proportion of small snow crab (approximately <30 cm), relative to the early 2000s. In 2011, the relative composition of male crab ≥95 mm was larger than that observed in the two preceding years, and was comparable to the levels seen in 2002, 2007 and 2008. However in 2011, the proportion of crab larger than 110 mm remained small, at a level comparable to that observed during the relatively low abundance years of 2001 and 2009.

In 2011, the highest densities of commercial-sized male snow crabs in the RV survey were observed just outside the Baie des Chaleurs, east of the Gaspé peninsula, in stratum 417 (Fig. 6). This observation is also reflected in the relatively high proportion of crab biomass found in that stratum in 2011, a level that was previously reached or exceeded only prior to 1991 (Fig. 4). Densities over the Magdalen shallows and the west of Cape Breton Island were greater than in 2009-2010, but not as elevated as during the high abundance years of 2004-2006 (Fig. 6).

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Table 1. Parameters for the two trawls used in the RV survey of the southern Gulf of St. Lawrence.

	Yankee 36	*Western IIA*
Years in operation	1971-1984	1985-present
Footrope	7" (outer sections) and 14" (inner sections) rubber disc spacers + 17 lb. iron spacers	21" (outer) and 18" (inner) rubber bobbins and 6.75" diameter 7" long rubber spacers
Footrope length	80'	106'
Headline length	60'	75'
Headline height	9'	15'
Wingspread	41'	41'
Door type	Steel bound wood	Portuguese (all steel)
Door weight	1,000 lb	1,800 lb
Lengthening piece liner	1.25"	1.25"
Codend liner	0.25"	0.75"

Table 2. Parameters for the vessels used in the RV survey of the southern Gulf of St. Lawrence for the years presented in this report.

	E.E. Prince	*Lady Hammond*	*CCGS Alfred Needler*	*CCGS Teleost*
Vessel type	Stern trawler	Stern trawler	Stern trawler	Stern trawler
Tonnage	406	897	959	2,405
Length	40 m	58 m	50 m	63 m

Figure. 1. Stratum boundaries for the southern Gulf of St. Lawrence September RV survey.

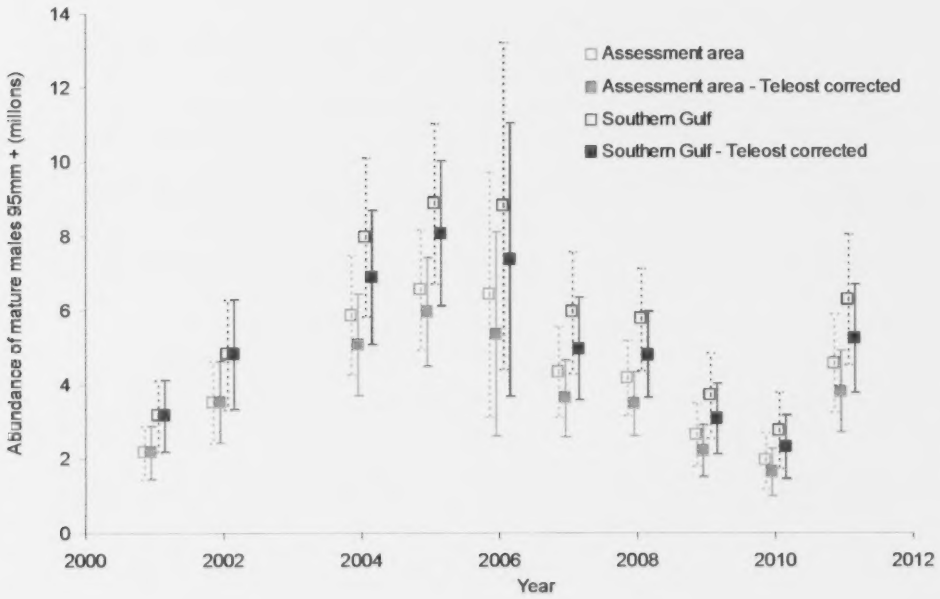

Figure 2. Trawlable abundance (millions ± 95% confidence interval) of adult male snow crab ≥95 mm in the RV survey 2001-2011, based on a geographic area comparable to that used for the current snow crab assessment (red) and for the entire RV survey area (blue). In each case, series are presented for Teleost catches that were (closed symbols) and weren't (open symbols) corrected for a possible difference in fishing efficiency between the CCGS Alfred Needler and the CCGS Teleost.

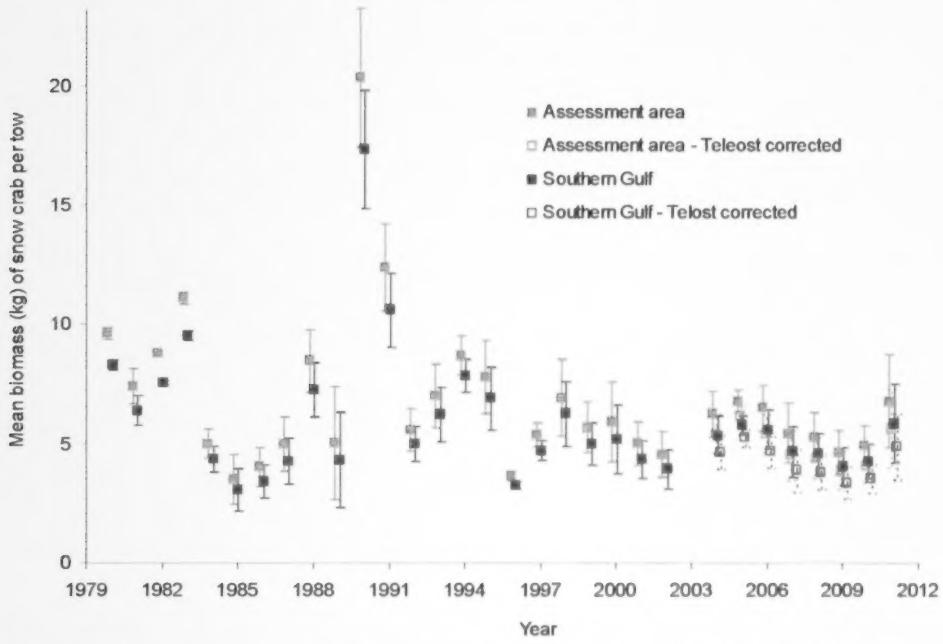

Figure 3. Biomass index (mean kg/tow ± 95% confidence interval) for all snow crab (male and female) in the RV survey 1980-2011, based on a geographic area comparable to that used for the current snow crab assessment (red) and for the entire RV survey area (blue). In each case, series are presented for Teleost catches that were (closed symbols) and weren't (open symbols) corrected for a possible difference in fishing efficiency between the CCGS Alfred Needler and the CCGS Teleost.

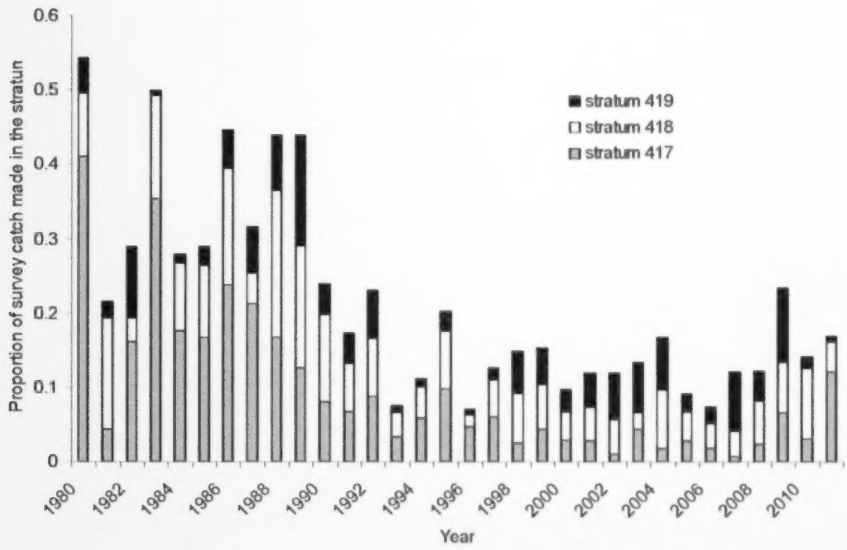

Figure 4. Annual proportion of total RV survey snow crab catches (males and females) made in the three strata in and immediately outside of Baie de Chaleurs (Fig. 1): stratum 419 (head of the bay), stratum 418 (mouth of the bay), and stratum 417 (north east of the mouth of the bay).

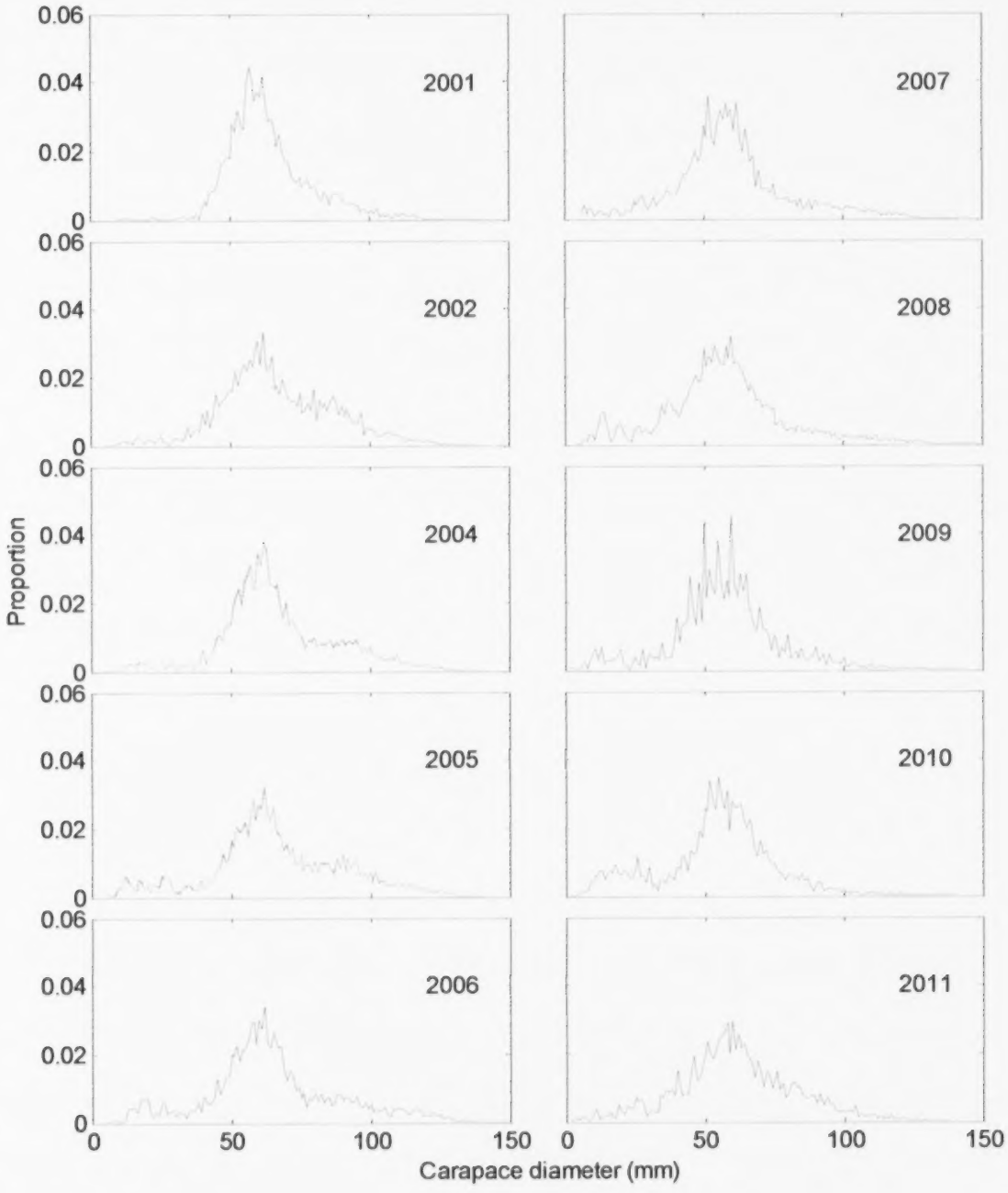

Figure 5. Annual survey-scale frequency distributions (expressed as proportions) of snow crab carapace diameter (males and females combined). In 2004 and 2005, two vessels were used to complete the survey and frequency distribution with (green) and without (blue) a correction factor for a possible difference in catchability are shown (note these distributions essentially overlap completely and the blue line is therefore not visible). Because the survey in 2003 was incomplete and was undertaken by an uncalibrated vessel, the data are not shown.

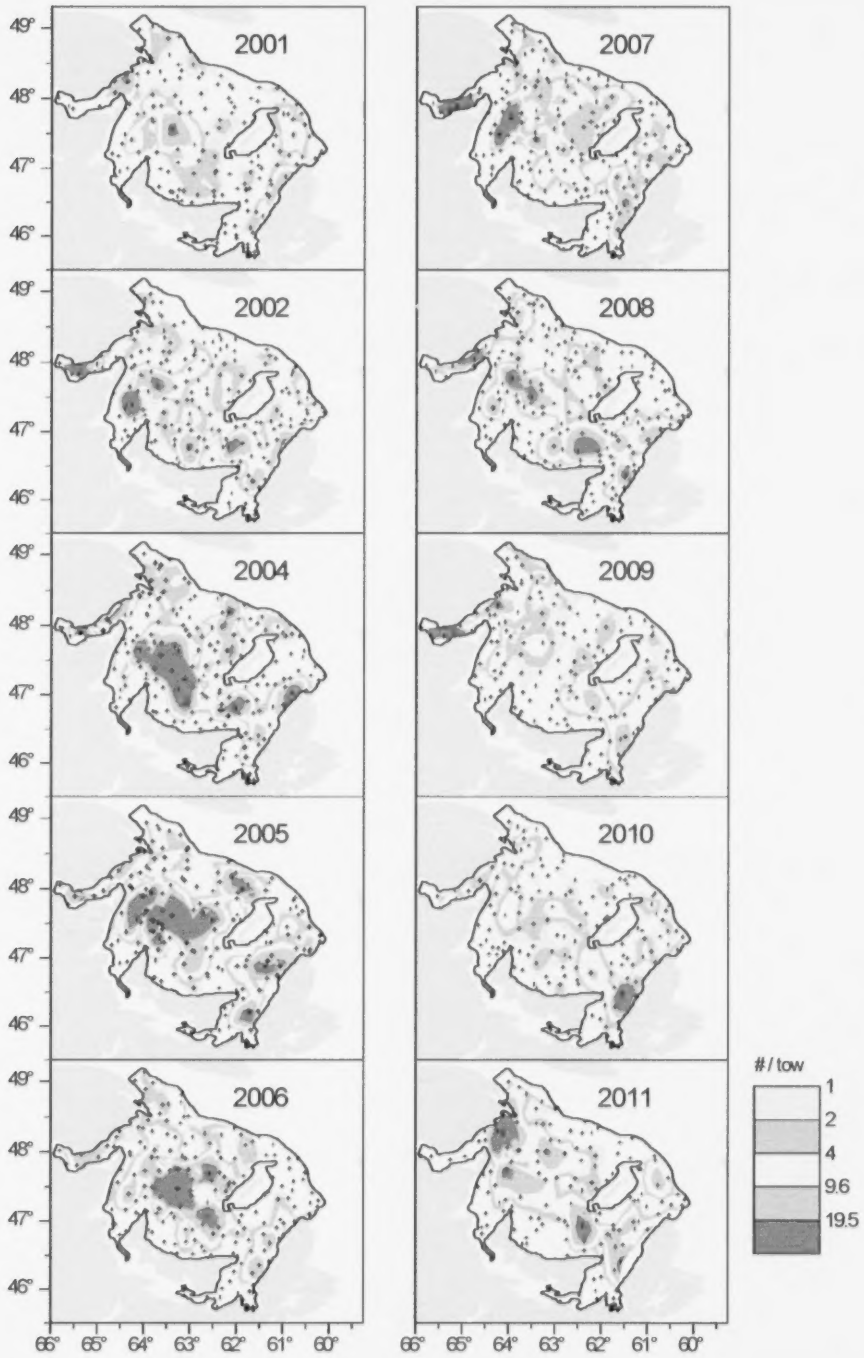

Figure 6. Annual geographic distribution of snow crab catch rates (males ≥95 mm) in the September RV survey, 2001-2011 (excluding 2003). The small crosses indicate the set locations. The contour levels represent the 10th, 25th, 50th, 75th and 90th percentiles of non-zero catches for the entire period.